N_2O emissions in corn/soybean systems: Fertilizer Management and Rotation Effects

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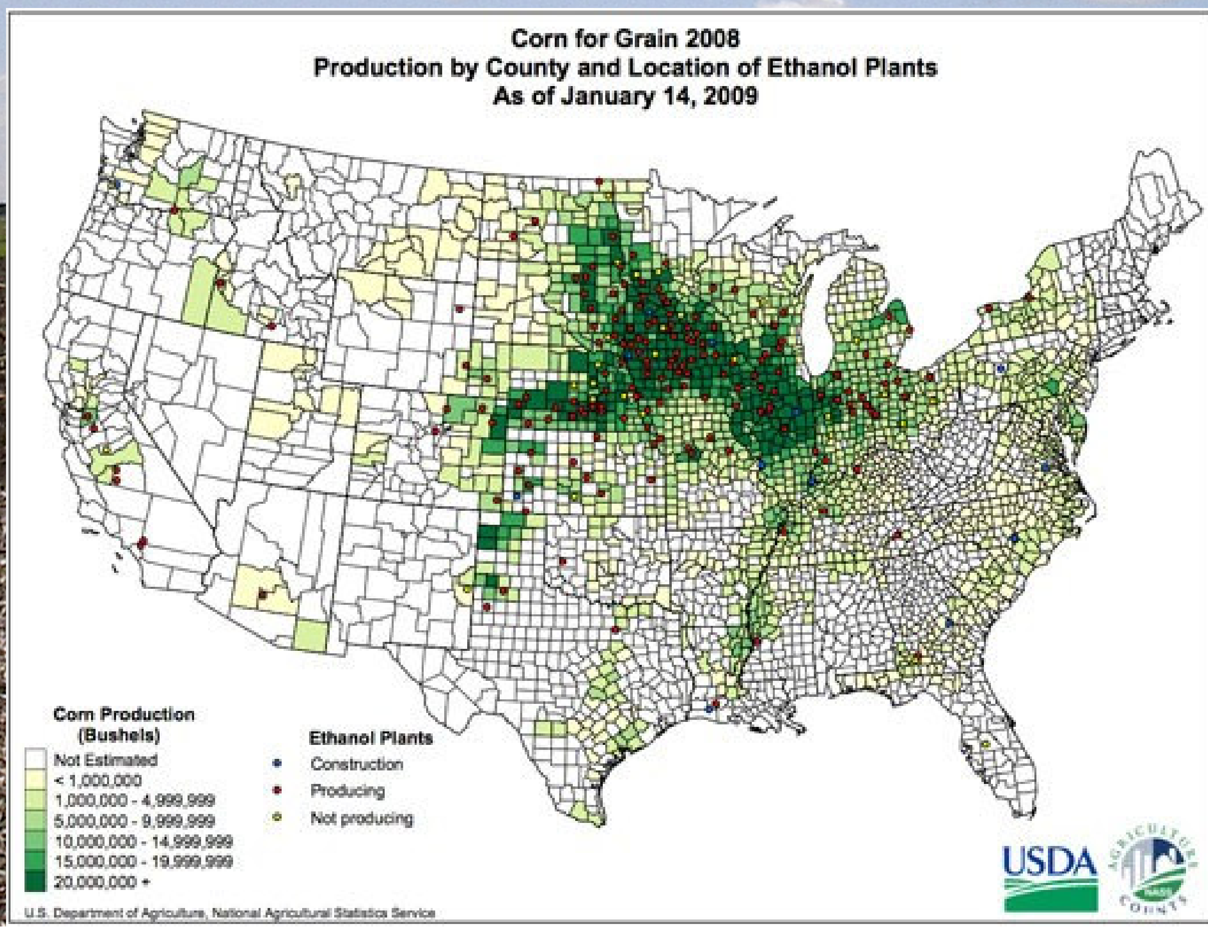
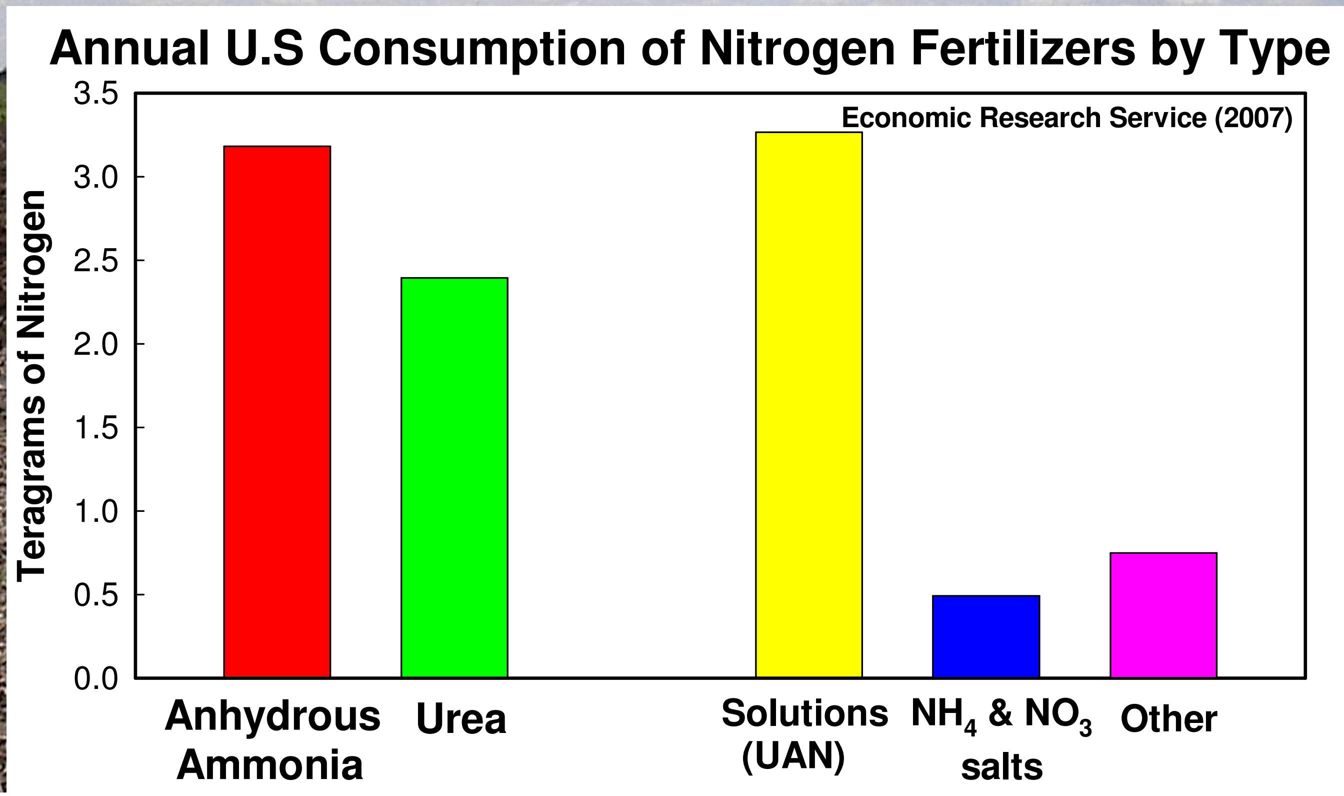
- Corn + soybeans = ~ 50% of total cropped land in U.S.
  - Improved estimates of GHG emissions:
    - National GHG inventory
    - Life cycle analysis of biofuel production
    - Establishment of C offset programs

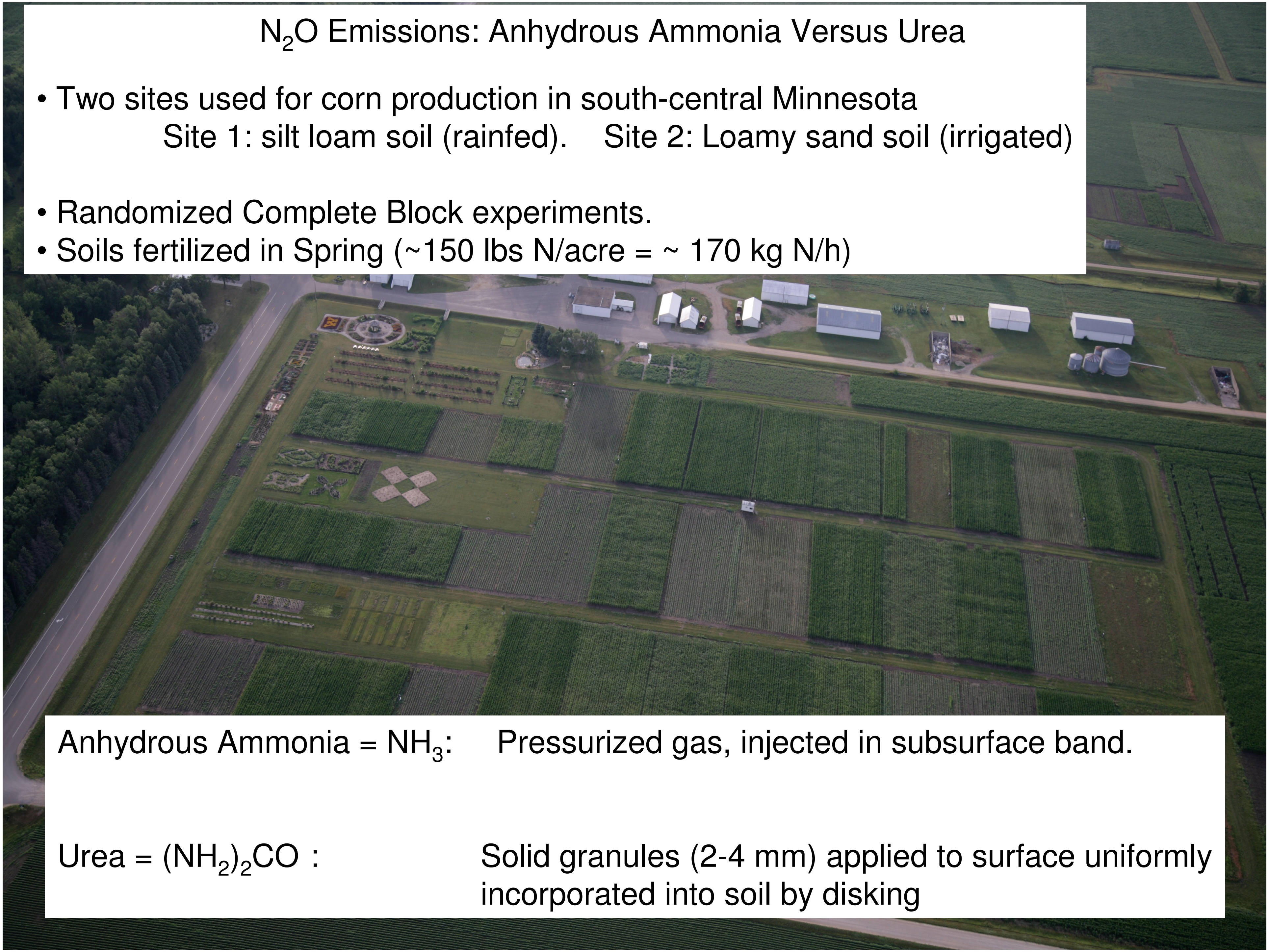
- Uncertainty regarding fundamental questions, e.g.:
  - Fertilizer mgmt practices & crop rotation effects



Does Fertilizer Form and Application Method Affect N_2O Emissions?

- Anhydrous ammonia and urea dominant in midwest
- Few studies with Anhydrous ammonia
  - 1 year of data comparing Anhydrous ammonia vs. Urea
- Emission models do not account for:
  - Chemical form, application method





N_2O Emissions: Anhydrous Ammonia Versus Urea

- Two sites used for corn production in south-central Minnesota
  Site 1: silt loam soil (rainfed). Site 2: Loamy sand soil (irrigated)

- Randomized Complete Block experiments.
- Soils fertilized in Spring (~150 lbs N/acre = ~ 170 kg N/h)

Anhydrous Ammonia = NH_3: Pressurized gas, injected in subsurface band.

Urea = $(NH_2)_2CO$: Solid granules (2-4 mm) applied to surface uniformly incorporated into soil by disking

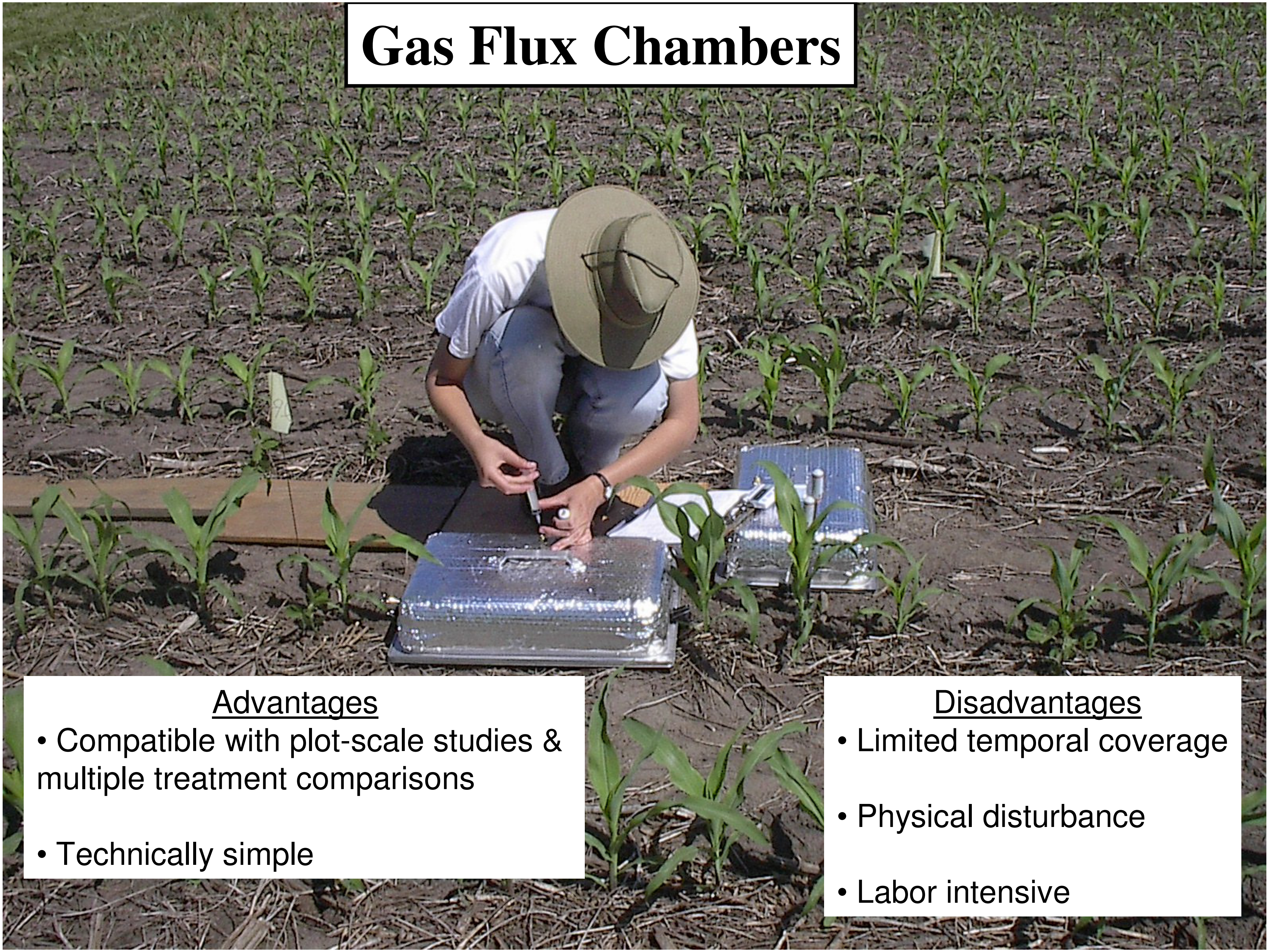
Anhydrous Ammonia Injection: Sidedress Application at Site 2

Knives inject pressurized NH_3 gas:

~ 7 inches (18 cm) below surface.

Concentrated band of Nitrogen between each corn row.

Gas Flux Chambers



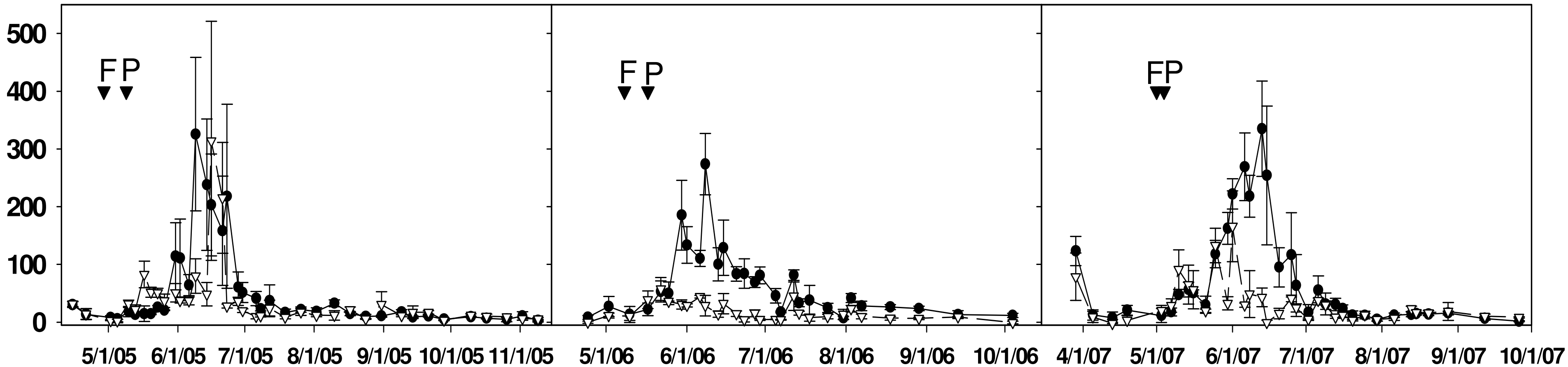
<u>Advantages</u>

- Compatible with plot-scale studies & multiple treatment comparisons
- Technically simple

<u>Disadvantages</u>

- Limited temporal coverage
- Physical disturbance
- Labor intensive

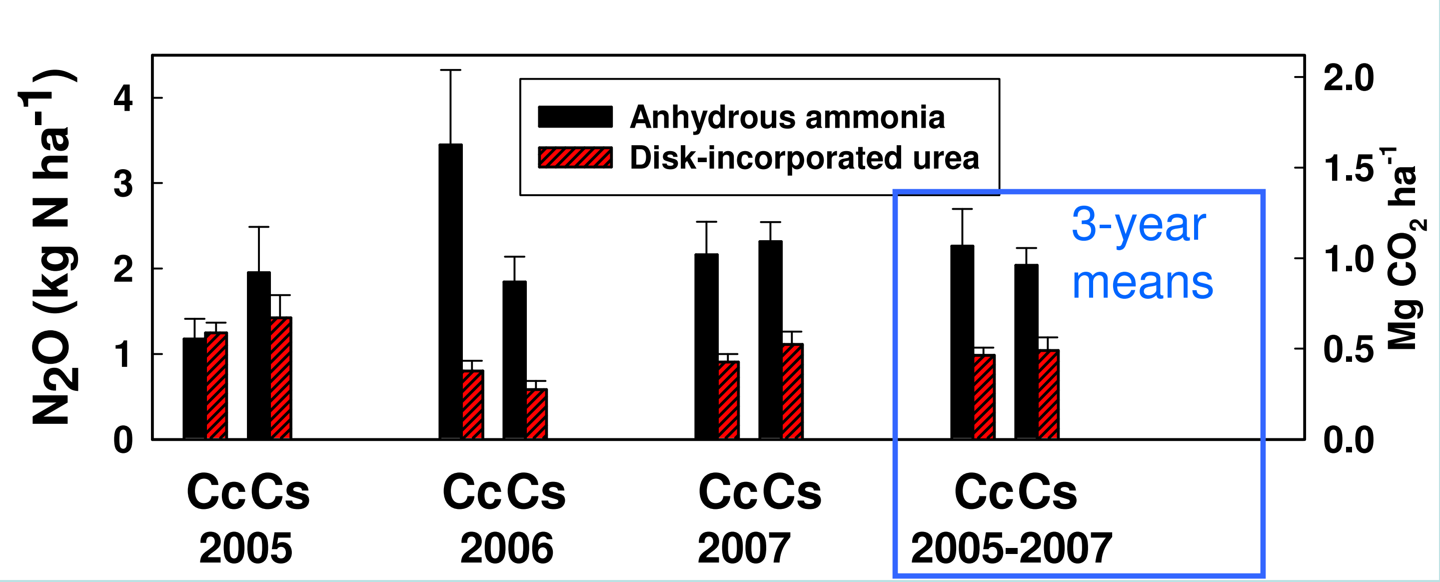
Daily N_2O flux (ug N m^{-2} h^{-1})
2005, 2006, 2007 Growing Seasons



F = Fertilizer application date
P = Planting date

Effects of Fertilizer Type: Anhydrous Ammonia (AA) versus Urea

N_2O emissions twice as high from AA



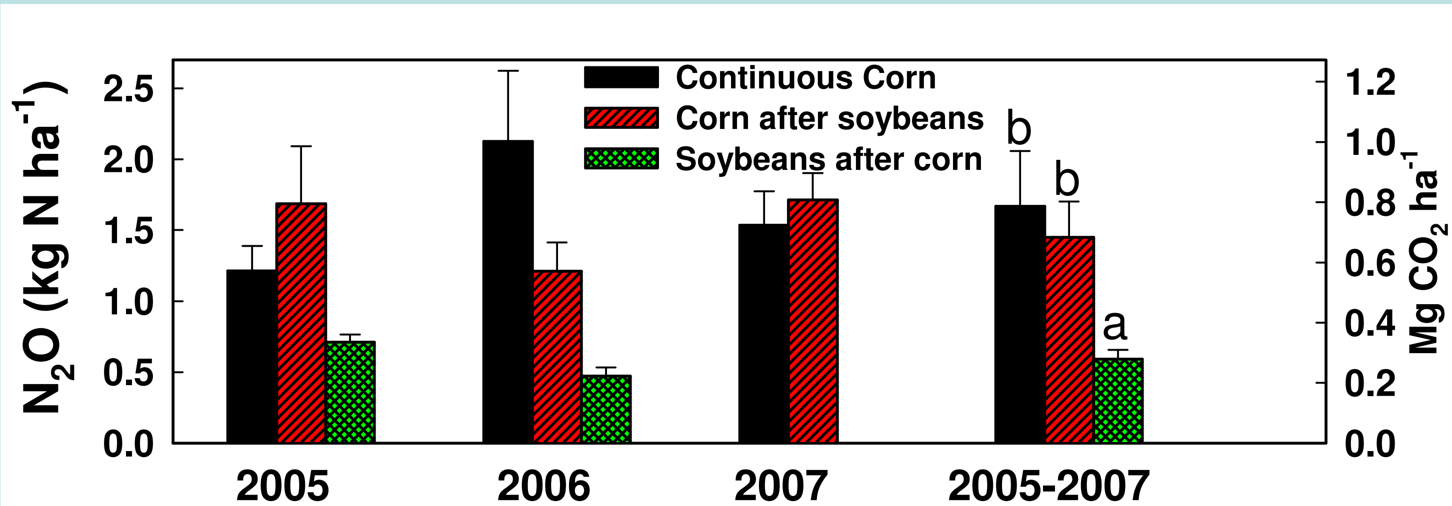
Two cropping systems:
Cc= Corn after Corn
Cs = Corn after Soybean

Venterea et al. 2010. SSSAJ.

Rotation Effects

N_2O Emissions averaged across fertilizer treatments for each crop.

- Continuous Corn (Cc)
- Corn after Soybean (Cs)
- Soybean after Corn (Sc): Not fertilized



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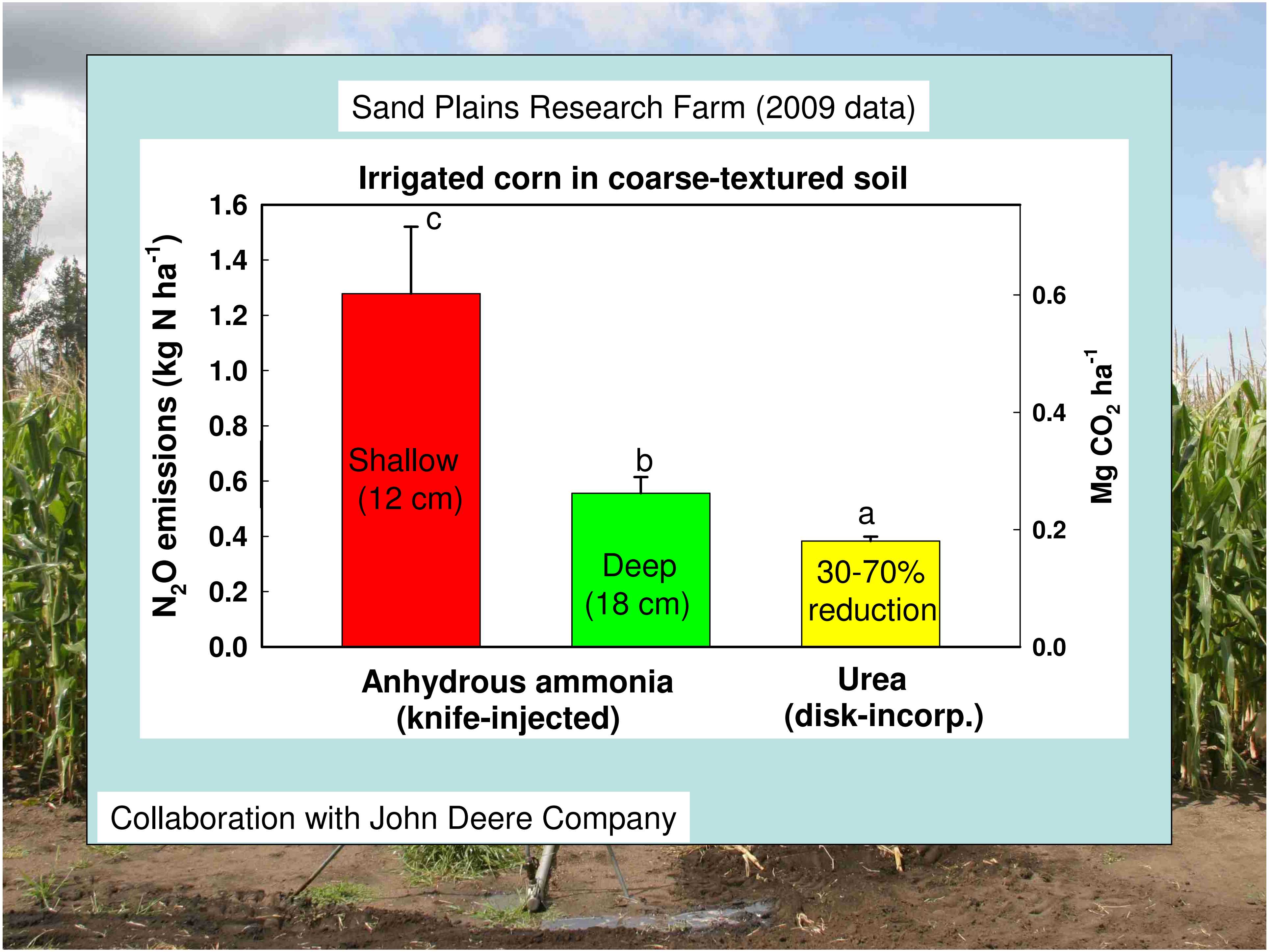
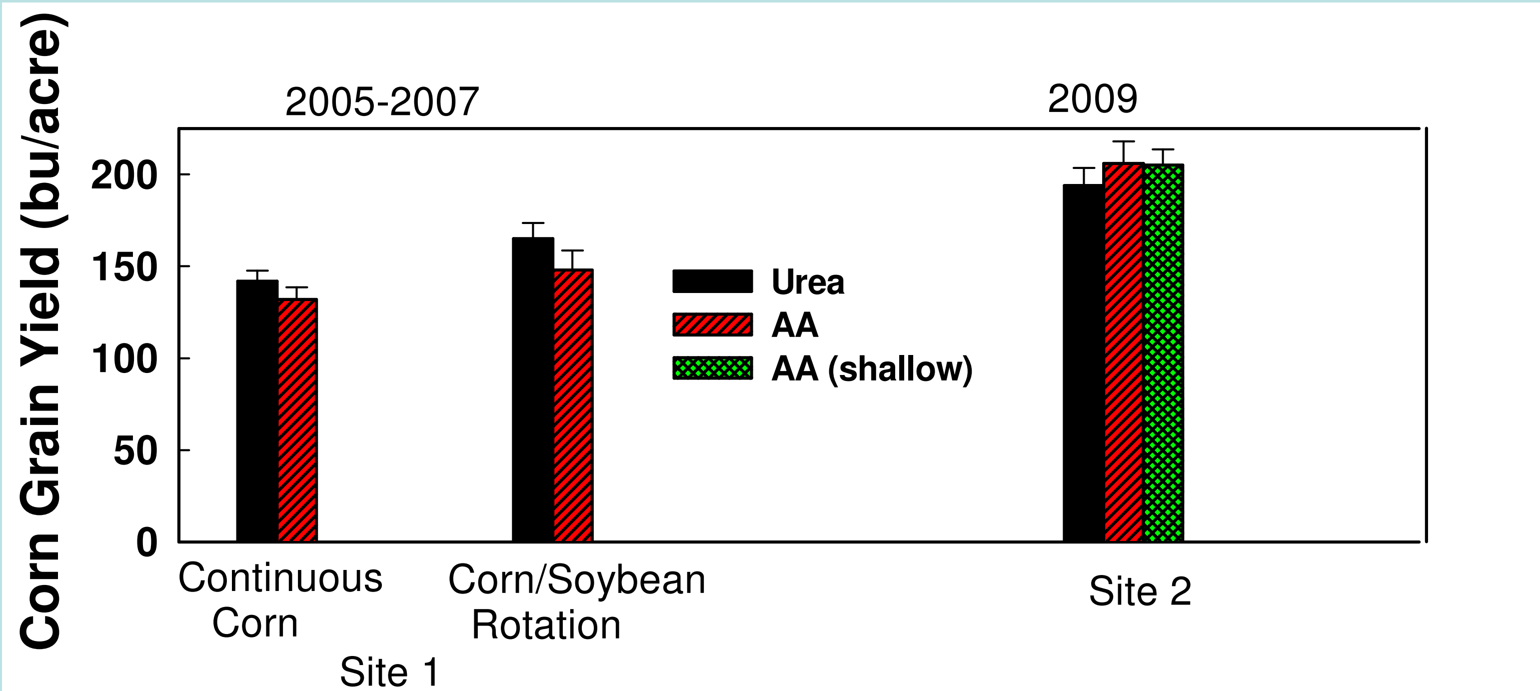


Sand Plains Research Farm (2009 data)
Irrigated corn in coarse-textured soil
N_2O emissions (kg N ha^{-1})
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Mg CO_2 ha^{-1}
0.6
0.4
0.2
0.0
c
Shallow (12 cm)
b
Deep (18 cm)
a
30-70% reduction
Anhydrous ammonia (knife-injected)
Urea (disk-incorp.)
Collaboration with John Deere Company

Grain Yields



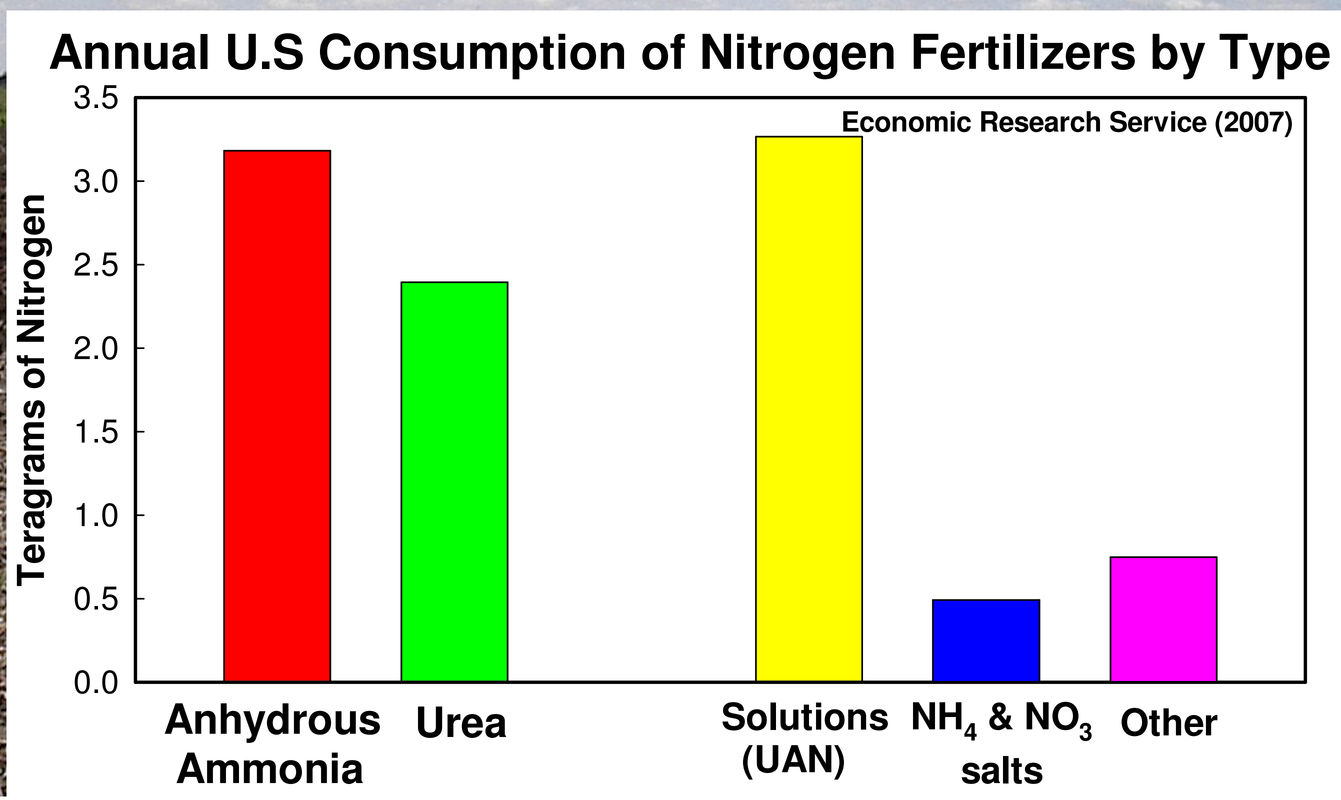
Site Specific GHG Impact of Management Changes

Using data from Site 1	Annualized CO_2 equivalents for a two-yr rotation
	<u>Mt C ha^{-1}</u>
Shift from AA to Urea	**GHG savings**
Continuous corn	-0.50
C/S rotation	-0.25
	(similar to reduced tillage)
Shift from C/S rotation to Continuous corn	**GHG cost**
Anhydrous ammonia	+0.37
Urea	+0.10 (-73%)

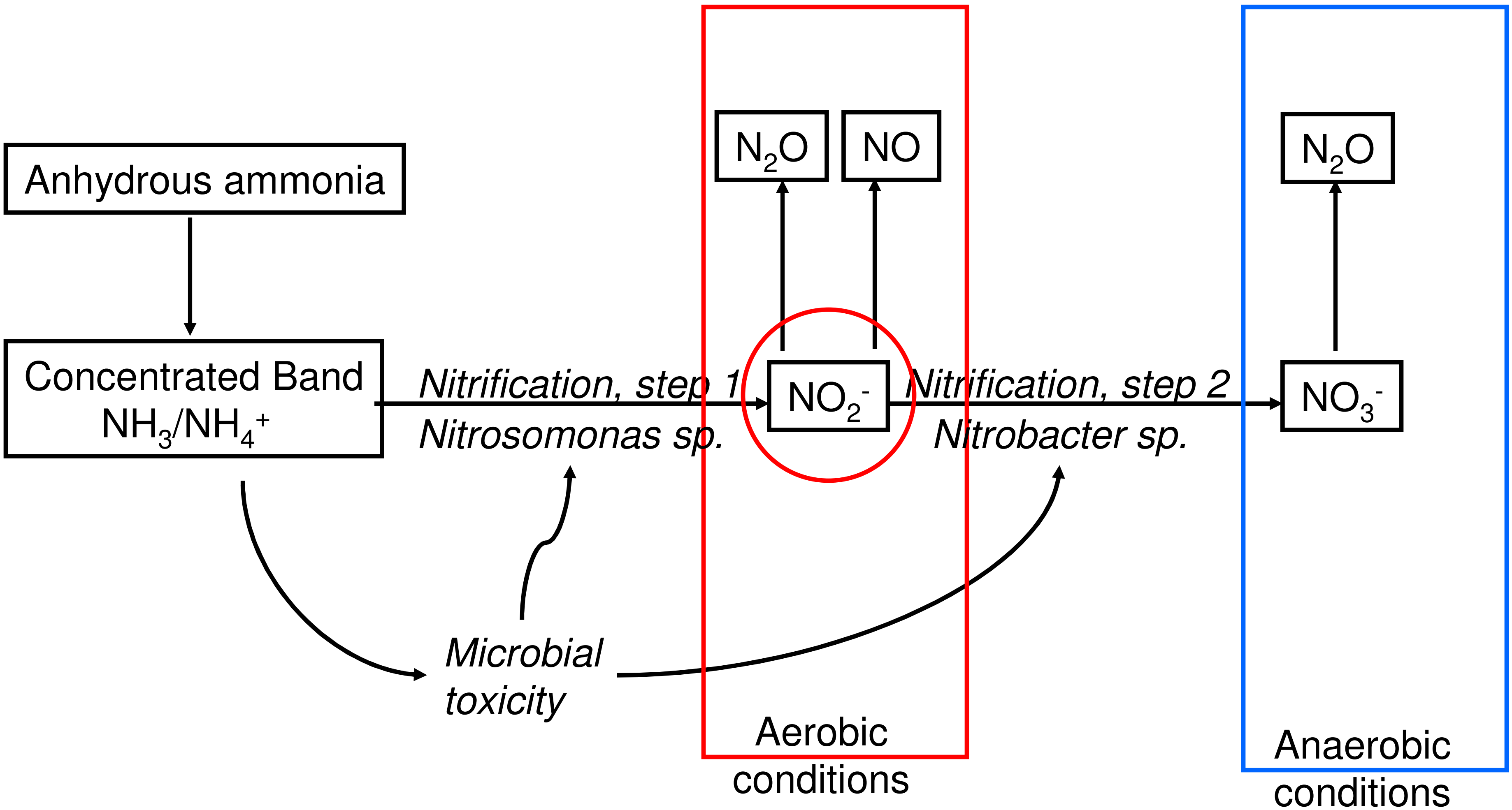
Impact on National-Scale GHG Emissions

- Assume: N_2O Emission factor for AA = 2 x EF of other fertilizer types

- Complete substitution of AA by other fertilizer types:
    - Reduce national N_2O emissions by 25%
    - Using EPA estimate of Direct Emissions from cropland (2006)
        - 0.25 x 140 Tg CO_2 = 35 Tg CO_2 saved per year



Higher N_2O Production With Anhydrous Ammonia



Venterea and Rolston, JEQ. 2000

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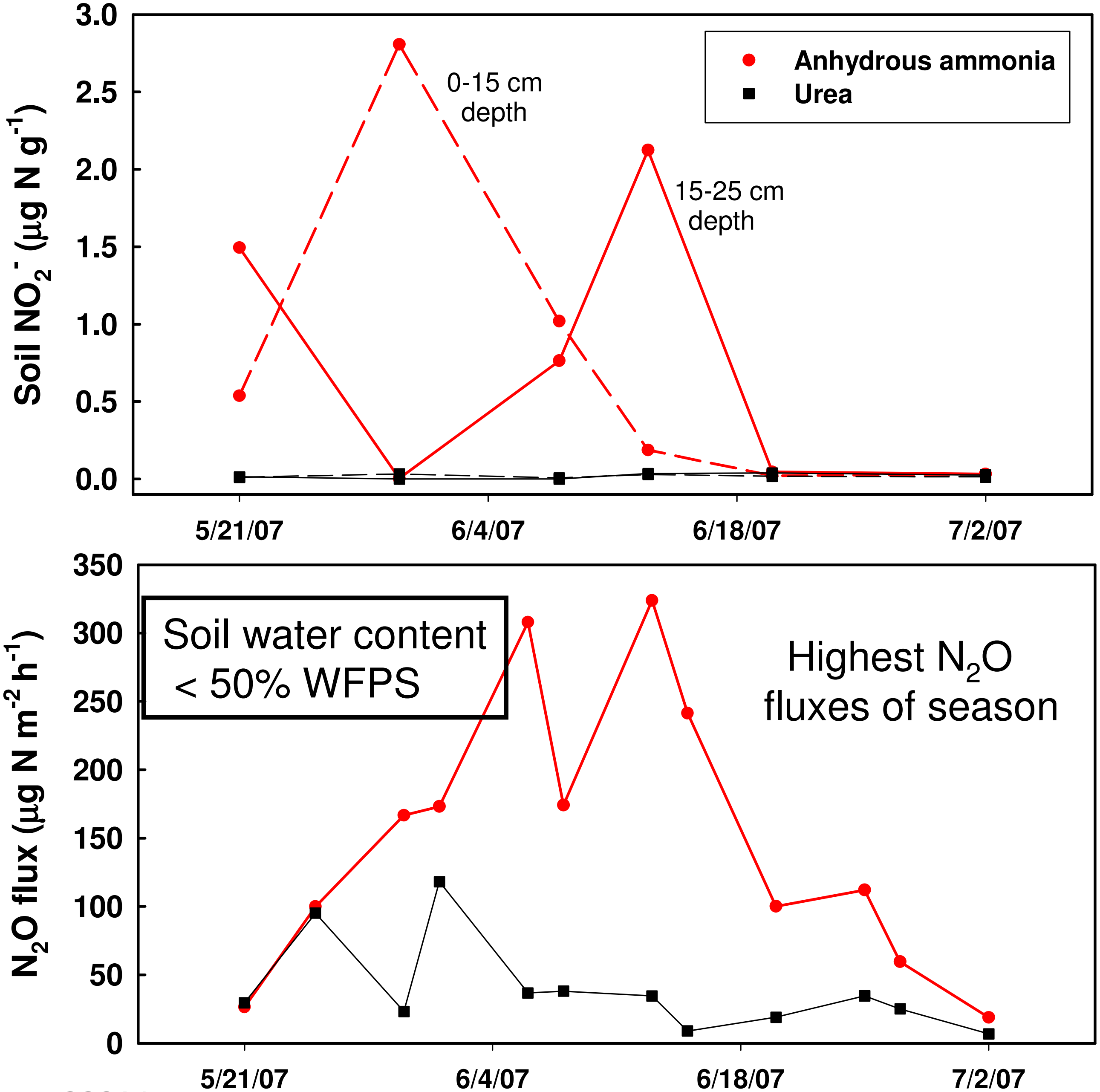

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Nitrification kinetics modeling

Monod kinetics with inhibition term(s)

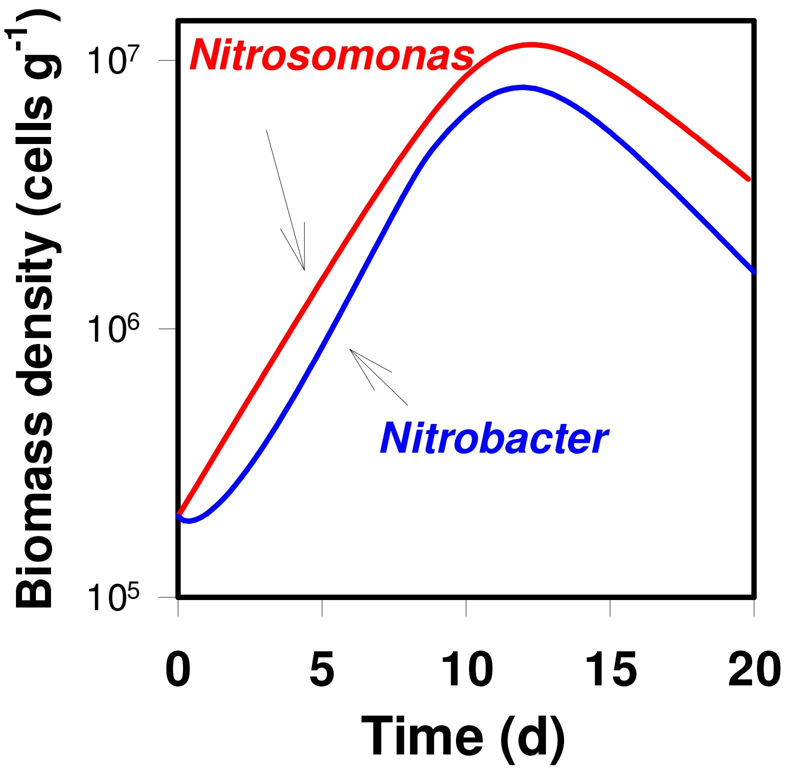
$$\frac{dB_j}{dt} = B_j\left(\frac{\mu_{\max,j}}{K_{s,j} + K_{inh} + C_j} C_j - d_j\right)$$

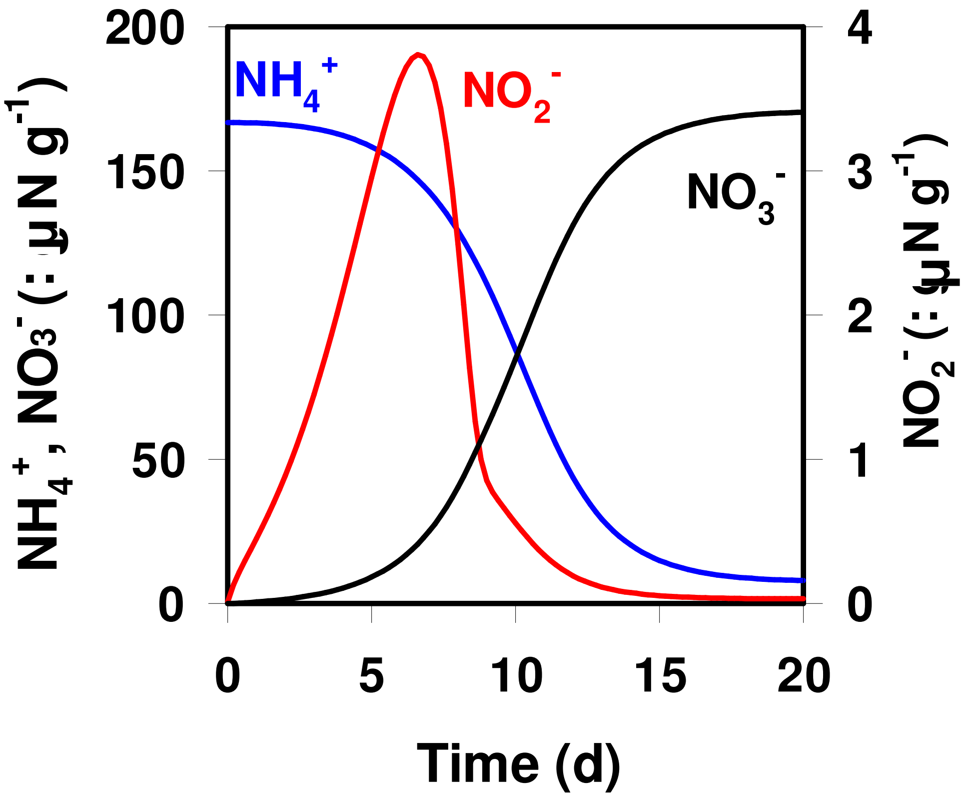
Venterea and Rolston, JEQ. 2000

Some degree of nitrite accumulation inherent to the nitrification process.

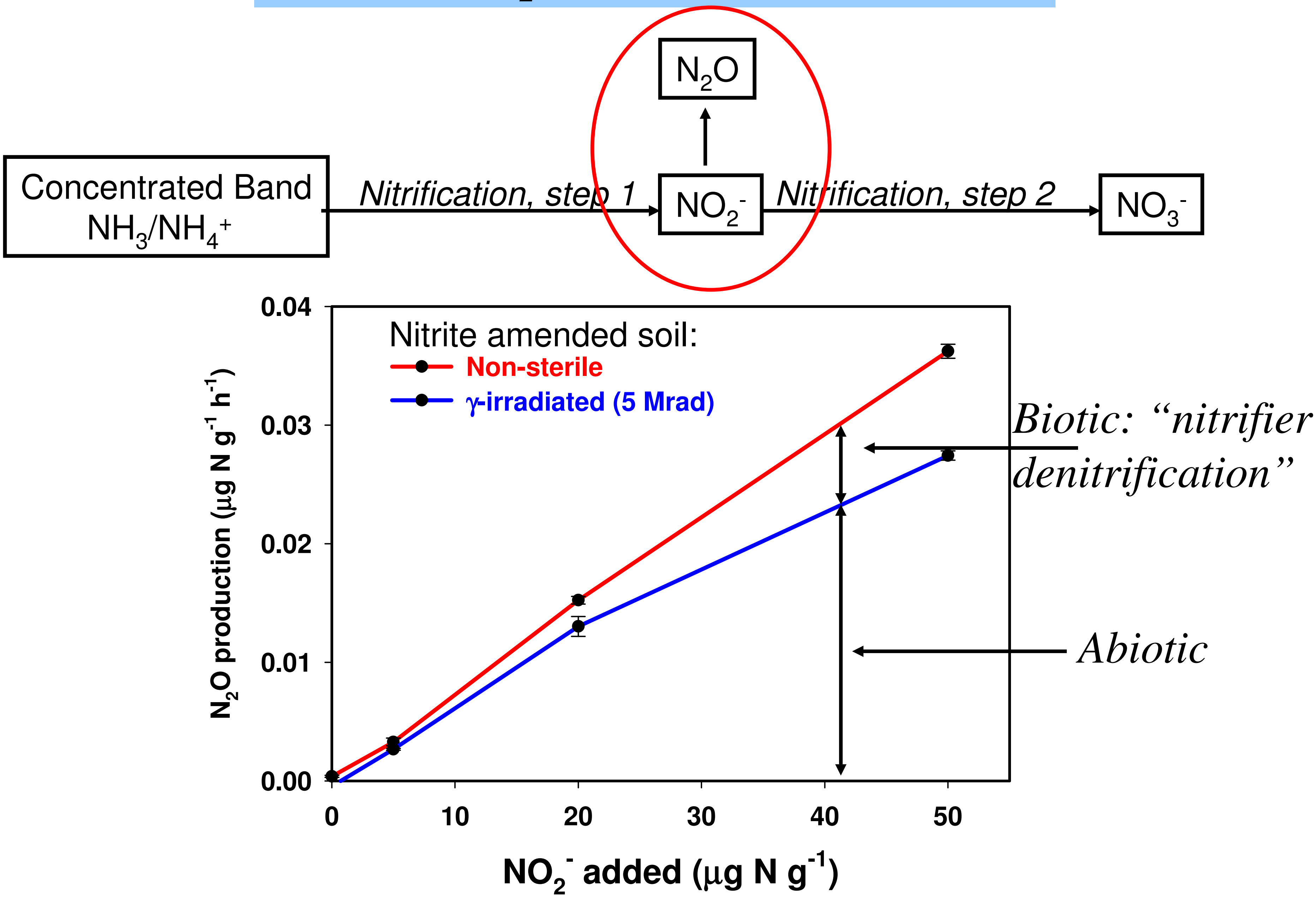
Amount and timing depends on toxicity effects.

Not understood well enough to predict dynamics at a given site.





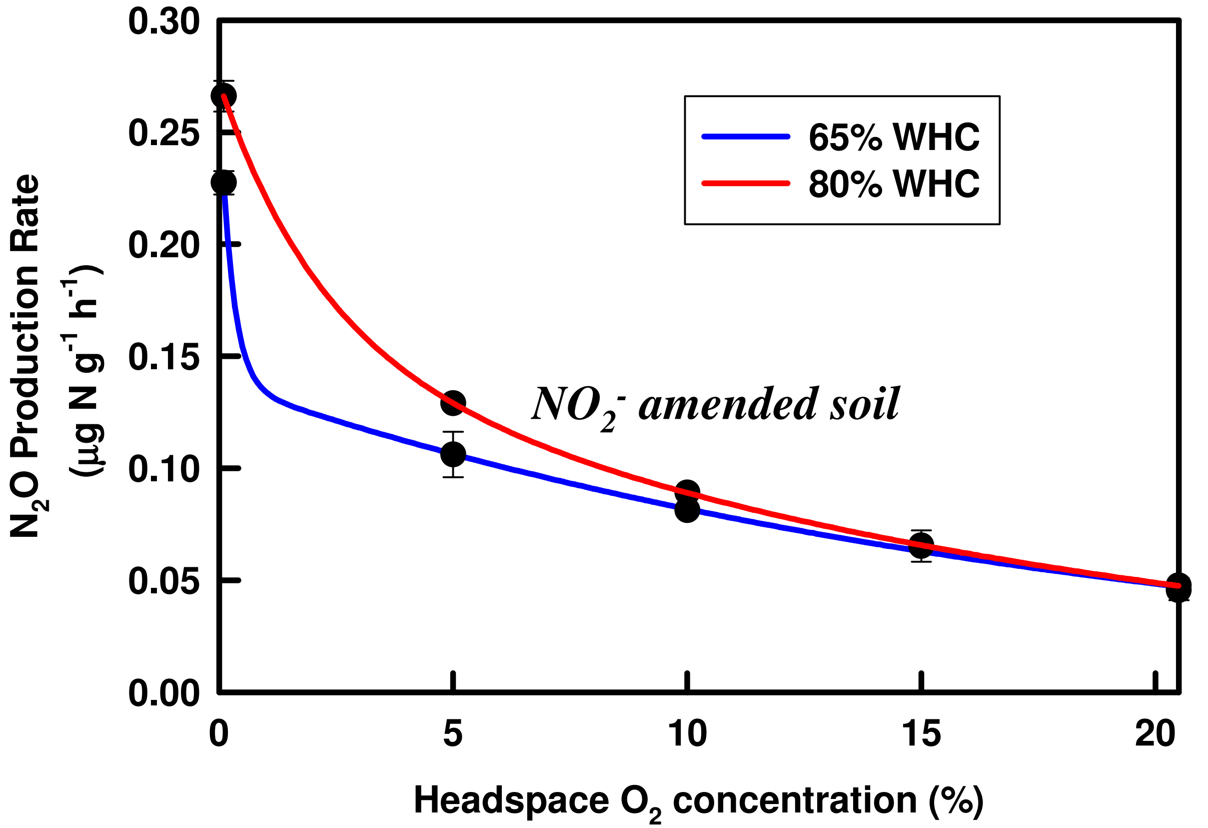
Kinetics of N_2O Production from Nitrite



Venterea, 2007. Global Change Biol. 13, 1798–1809.

Nitrifier Denitrification Response to Oxygen Status

Biological component: Gradually increasing N_2O production as O_2 decreases.



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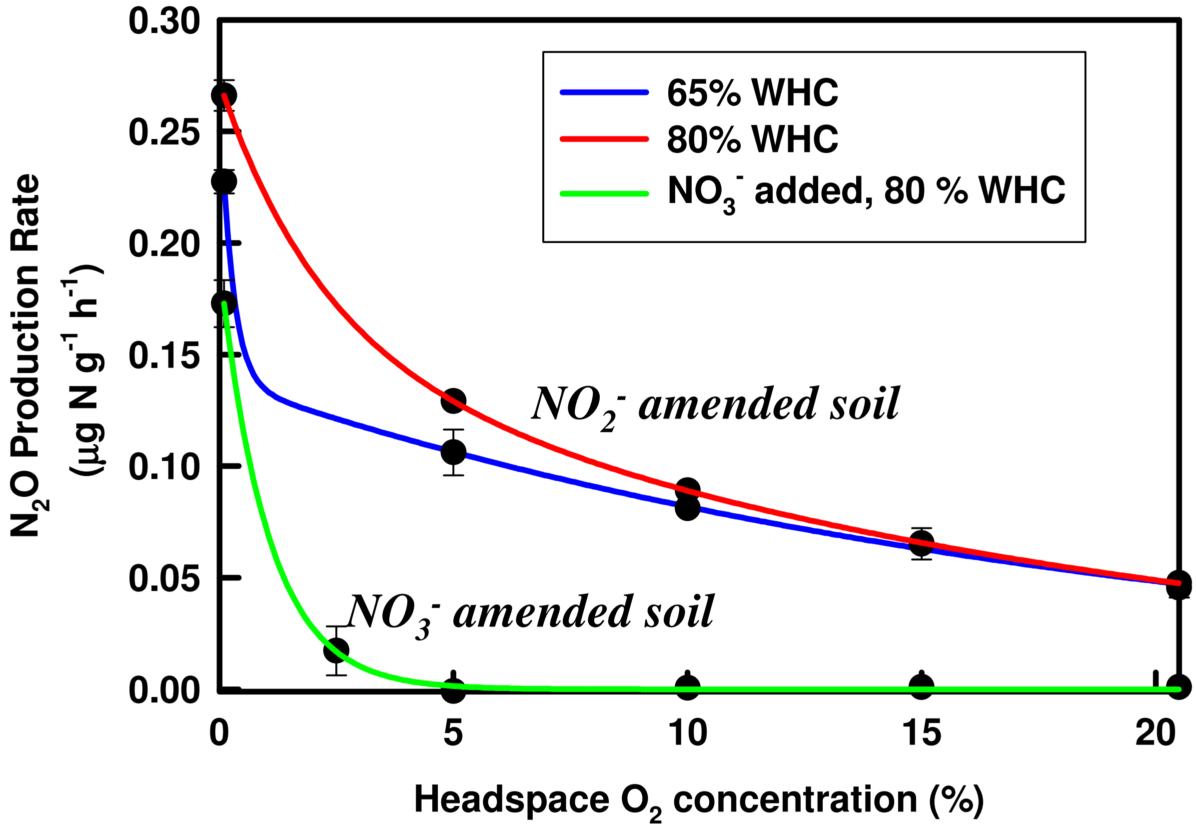
Nitrifier Denitrification Response to Oxygen Status

Biological source responds differently than denitrification
(abrupt increase when $O_2 < 5\%$)



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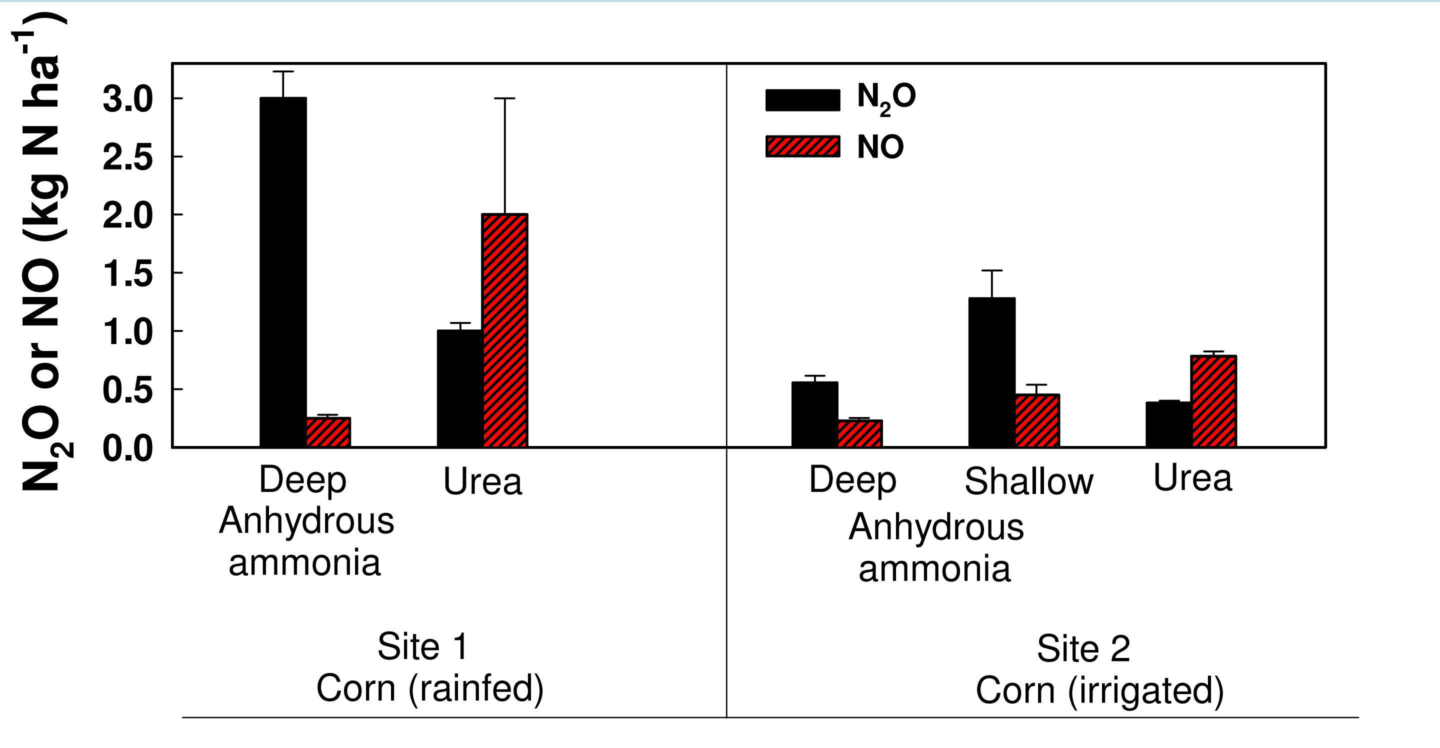
Nitric Oxide (NO) Emissions

- Pattern is opposite compared to N_2O.
- $NO:N_2O$ ratio for urea = 2 compared to < 0.4 for AA.
- High NO reactivity in soil



Concluding Remarks / Directions

- Fertilizer form and placement matter
  - Side-by-side studies needed, different sites & soils.
  - In denitrification-dominated soils, results could be different.

- Not clear if effect in AA treatment due to the chemical form, or banding.
  - Same effect might occur in cases where urea is banded.

- Models & inventories not accounting for important sources of variation
  - Fertilizer Use data are available, could be combined with improved emissions models to develop more accurate inventories